ROOF BOLTING AND DUST CONTROL

BY JAMES WESTFIELD, FLOYD G. ANDERSON, C. W. OWINGS,
JOHN P. HARMON, AND LESLIE JOHNSON

* * * * * * * * * **Information Circular 7615**

MARCH 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

Work on manuscript completed June 1951. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7615."

August 1951

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James Westfield,[1] Floyd G. Anderson,[2] C. W. Owings,[3]
John P. Harmon,[2] and Leslie Johnson[2]

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[1] Chief, Accident Prevention and Health Division, Region VIII, Bureau of Mines, Pittsburgh, Pa.

[2] Mining engineer, Health Branch, Central Experiment Station, Pittsburgh, Pa.

[3] Mining engineer, Accident Prevention and Health Division, College Park, Md.

Information Circular 7615

INTRODUCTION

Drilling for roof bolting has created a new dust problem for the coal-mining industry. Drilling is inherently dusty, and control of dust produced by drilling vertical or nearly vertical holes is much more difficult than control of that produced by drilling flat or down holes.[4] Also, the dust produced by roof drilling differs in composition from that produced by drilling or cutting the coal face because it contains a significantly greater amount of free silica and therefore presents a greater potential hazard of silicosis.

Roof bolting has been practiced successfully in the mines of the St. Joseph Lead Co. in southeastern Missouri for over 20 years, but it was not until 1947 and 1948 that large-scale roof-bolting experiments were conducted in coal mines.[5] Although the need for dust control in conjunction with roof drilling was recognized from the beginning, the development and acceptance of roof bolting progressed so rapidly during 1949 and 1950 that solution of the dust problem lagged behind other engineering phases of the technique.

SUMMARY

Roof drilling without dust control presents a health hazard, as men working in the path of return air from the place where drilling is being done may be exposed to dangerously high concentrations of silica-bearing dusts.

Dust-control methods are not used in conjunction with roof drilling at 71 percent of all coal mines where roof bolting is being practiced in Region VIII.[6]

Wet pneumatic drilling, if properly conducted, results in acceptable control of dust concentrations, but it can affect the mine roof and floor adversely, is a disagreeable task, particularly in low coal, and requires a water-distribution system or the use of inconvenient pressure tanks.

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[4] Brown, C. E., and Schrenk, H. H., Effect of Angle Drilling on Dust Dissemination: Bureau of Mines Rept. of Investigations 3381, 1938, 7 pp.

[5] Thomas, E., Roof Bolting in the United States: Bureau of Mines Inf. Circ. 7583, 1950, 8 pp.

[6] Region VIII is comprised of 17 Northeastern States. More than 80 percent of the coal production of the United States is in this area.

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The development of dust collectors has been stimulated by the need for overcoming objectionable features that accompany wet pneumatic roof drilling and by the fact that collectors can be adapted to electric rotary drills. The Bureau of Mines has inaugurated a program for testing the effectiveness of dust-collecting devices developed commercially for application to roof drilling in coal mines, and the test work has progressed far enough to demonstrate that the principles applied in these dust collectors are adequate.

Control of the dust produced by roof drilling is difficult but must be accomplished. Proper application of wet methods and development of supplementary devices should solve the problem successfully.

FREE SILICA CONTENT OF ROOF STRATA AND ITS RELATION TO AIR-BORNE DUST

The roof generally is bolted where the immediate roof is soft and in many instances where the roof bolts can be fastened firmly into a harder or more substantial formation above. The strata found in drilling a roof are coal, shale, sandstone, limestone, and all the impure and intermediate variations of these materials. A comprehensive study of the geologic sections of the immediate roof of mines in Region VIII of the Bureau of Mines where roof bolting is in progress reveals that 67.7 percent of the footage of all the holes drilled for roof bolts is in shale, 23.4 percent is in sandstone and sandy shale, 7.1 percent is in coal and coaly shale, and 1.8 percent is in limestone. Shale consists chiefly of kaolin, muscovite, and quartz, with small amounts of many other minerals. Sandstone consists principally of quartz, with a cementing material of silica, calcite, or limonite. Limestone consists chiefly of calcite, with varying amounts of quartz. Even coal may contain a small percentage of quartz. Thus, quartz is present in significant amounts in about 91 percent of all the rock drilled for roof bolting.

The free-silica content of a mineral material (quartz is the most abundant form of free silica) is determined most accurately by the X-ray diffraction method, which is based upon the specific diffractive properties of crystalline substances.7/ This method requires only a small sample, and the small particle size of industrial dusts does not affect the results adversely. This method of determining free silica content was developed in part by the Bureau of Mines, and it is now used for quantitative analysis of samples of rock, rock dust, drill cuttings, and air-borne dust.

The free-silica content of the roof strata of 51 coal mines has been determined by X-ray diffraction analysis from roof rock, drill cuttings, and midget-impinger samples of air-borne dust collected in mines in 9 Eastern States. The average free-silica content of 80 samples from these mines is 31 percent, and it ranges from 7 to 88 percent. The free-silica content of the roof strata of 43 of the mines classified as having shale roof averages 26.5 percent and ranges from 7 to 62 percent. The free-silica content of the roof strata of 8 of the mines classified as having sandstone roof averages 55 percent and ranges from

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7/ Ballard, J. W., Oshry, H. I., and Schrenk, H. H., Quantitative Analysis by X-ray Diffraction. 1. Determination of Quartz: Bureau of Mines Rept. of Investigations 3520, 1940, 10 pp.

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31 to 88 percent. These results show that wide variation may exist in the composition of various roof strata and that the content of free silica encountered in drilling a shale roof may equal or exceed that found in drilling a so-called sandstone roof.

Although the composition of a mineral source material may not be considered an exact index of the composition of air-borne dust produced by mechanical disintegration of the material, some evidence on this subject is available. Unpublished data developed by the Bureau of Mines indicate that the quartz content of air-borne dust decreases as the time of settling increases, and direct comparison of analyses available in the Health Branch of the Bureau of Mines also indicates that the free-silica content of the air-borne dust produced by drilling is somewhat, but not significantly, less than the free-silica content of the material drilled. These results, though too limited to be conclusive, give some justification for using the analysis of the source material in evaluating the dust hazard, particularly as the error, if any, is on the side of safety. It may be pointed out, also, that Industrial Code 33 of the State of New York, "Control of Silica Dust in Rock Drilling," bases its definition of "injurious silica-dust concentration" upon analysis of the source material drilled.

DUST CONCENTRATIONS PRODUCED BY ROOF DRILLING WITHOUT DUST-CONTROL EQUIPMENT

Dust concentrations recently observed in five mines where stoper-type pneumatic drills are used without dust-control equipment averaged 607 million particles per cubic foot of air and ranged from 51 to 1,194 million particles per cubic foot. In six mines where electric rotary drills were used without dust-control equipment, the dust concentration averaged 313 million particles per cubic foot and ranged from 10 to 1,185 million particles per cubic foot. The dust concentrations cited are indicative of the dust exposure of the driller but were obtained under such variable conditions that they should not be used for direct comparison. For instance, the averages indicate that pneumatic drilling produces twice as much dust as electric rotary drilling; actually, the ratio may be higher. The ranges indicate that either type of drill may produce dust concentrations higher than 1 billion particles per cubic foot of air. This amount of dust can so pollute the air as to constitute a serious menace to the health not only of the drillers but of any persons working in the return air from the place where drilling is being done.

ALLOWABLE DUST CONCENTRATIONS APPLICABLE TO ROOF DRILLING

Any dust breathed in large quantities over a long period can impair the health of a worker, and silica is recognized as definitely harmful when inhaled into the lungs. Coal dust is less harmful but should not be considered completely harmless.

The hazard of exposure to silica-bearing dust is commonly gaged by the number of dust particles found in a unit volume of air and the free-silica

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content of the dust. Limits for occupational exposure expressed in such terms have been suggested by evaluation of the results of numerous clinical and engineering studies.[8][9][10]

The Bureau of Mines has made the following tentative recommendations on allowable limits of air dustiness:

> In bituminous-coal and lignite mines, the average full-shift concentration of atmospheric dust to which a workman may be exposed should not exceed 20 million particles per cubic foot of air, and a maximum concentration for any single operation should not exceed 40 million particles of dust per cubic foot of air. When the dust contains silica, not more than 5 million particles of silica dust per cubic foot of air should be present in the above limiting concentrations. The dust count may be multiplied by the percentage of silica concentration, and if the result is less than 5 million the dust concentration will be considered safe. The above limiting concentrations are based on impinger samples in which light-field counts[11] are made under a microscope.

As shown in figure 1, to maintain these standards a dust concentration higher than 18.9 million particles per cubic foot of air would not be allowable when the average shale roof is drilled, and a dust concentration higher than 9.1 million would not be allowable when the average sandstone roof is drilled. A dust concentration no higher than 5.7 million would be required in some instances.

ROOF-DRILLING AND DUST-CONTROL PRACTICES IN REGION VIII OF THE BUREAU OF MINES

Table 1 lists the types of drilling equipment used for roof drilling, the number of mines using each type, and the number of mines using or not using dust-control methods with each type. It can be seen that at 71.1 percent of the mines, roof is drilled with no dust-control equipment; contrary to the Bureau of Mines recommendation that a dust respirator is not to be used as a substitute for dust-control measures,[12] reliance is placed upon the protection offered by respirators.

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[8] National Silicosis Conference, Report on Medical Control, Final Report of the Committee on the Prevention of Silicosis Through Medical Control: U. S. Dept. of Labor, Div. of Labor Standards, Bull. 21, pt. I, 1938, 79 pp.

[9] Sayers, R. R., Bloomfield, J. J., Dallavalle, J. M., Jones, R. R., Dreessen, W. C., Brundage, D. K., and Britten, R. H., Anthracosilicosis Among Hard Coal Miners: U. S. Pub. Health Bull. 221, 1936, 113 pp.

[10] Flinn, R. H , Seifert, H. E., Brinton, H. P., Jones, J. L., and Franks, R. N., Soft Coal Miners Health and Working Environment: U. S. Pub. Health Bull. 270, 1941, 113 pp.

[11] Brown, C. E., and Schrenk, H. H., A Technique for Use of the Impinger Method: Bureau of Mines Inf. Circ. 7026, 1938, 20 pp.

[12] Pearce, S. J., The Use of Dust Respirators in Coal Mines: Bureau of Mines Inf. Circ. 7561, 1950, 6 pp.

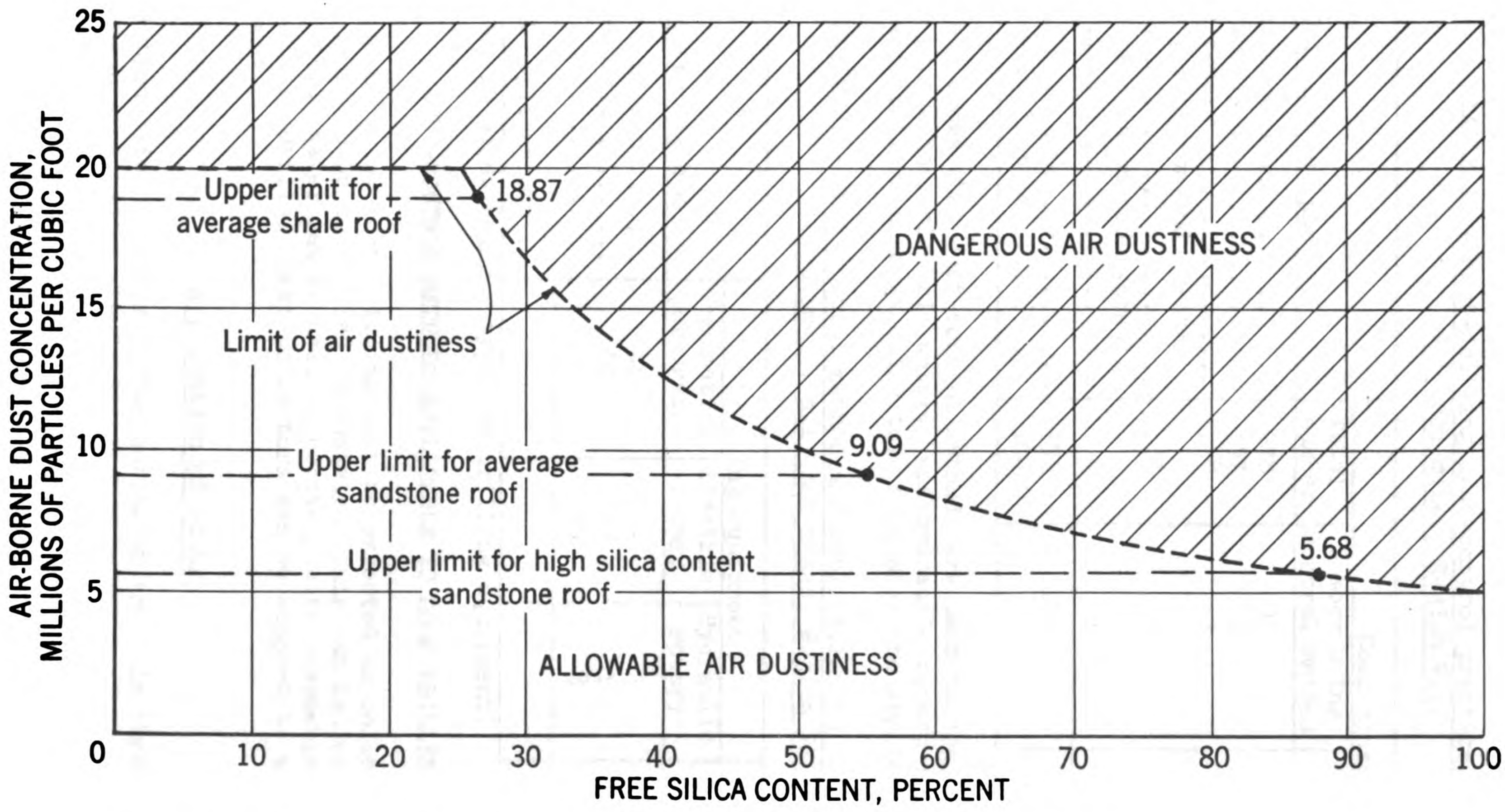

Figure 1. - Allowable atmospheric-dust concentrations relative to free-silica content. Tentative Bureau of Mines recommendations for bituminous coal and lignite mines.

TABLE 1. - Roof-drilling dust-control practice, all coal mines, Region VIII

Drilling equipment	Coal mines Total number	 Number using control method	 Number not using control method
Pneumatic percussion.............	278	91	187
Electric rotary..................	57	2	55
Hydraulic rotary.................	8	3	5
Pneumatic percussion and electric rotary.........................	6	5	1
Pneumatic percussion and hydraulic rotary.........................	4	1	3
Total, all types.............	353	102	251
Percent, all types...........	100.0	28.9	71.1

Table 2 shows what dust-control methods are used in conjunction with pneumatic percussion, electric rotary, and hydraulic rotary drills. Note that the applications of dust collectors outnumber the applications of water.

TABLE 2. - Dust-control method and application to drilling equipment, all coal mines, Region VIII

Dust-control method	Drilling equipment Pneumatic percussion	 Electric rotary	 Hydraulic rotary	Totals Number	 Percent
Application of water......	46	-	3	49	13.5
Dust collector...........	51	7	1	59	16.3
None.....................	191	56	8	255	70.2
Total applications...				1/363	100.0

1/ Includes 10 mines using 2 types of drilling equipment.

DUST-CONTROL METHODS APPLICABLE TO ROOF DRILLING

Dust produced by roof drilling must be arrested or collected at its source if it is to be controlled adequately. This can be done by water or a dust collector. Water can be used effectively with pneumatic percussion or hydraulic rotary drills. Dust collectors can be adapted to any type of drilling equipment.

Application of Water

The introduction of water to the bottom of the hole through the drill steel has been accepted as standard practice in metal mines using pneumatic percussion drills. This practice is applicable to roof drilling; it complies with the Federal Mine Safety Code requirements and suitable drilling equipment is immediately available to the coal-mine operators. Successful control

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by this method[13] depends mainly upon maintaining the flow of water through the drill steel, using water continuously during the drill-operating period, and providing positive ventilation as needed. High dust concentrations can result if too little water is used, especially when vertical holes are drilled with a stoper-type drill. It is advisable to maintain an adequate water pressure so that there is a full flow of water. Collaring dry - that is, drilling the first few inches of hole before opening the water valve - can also cause high dust concentrations and should not be allowed. During recently observed roof drilling with a wet stoper drill, dust concentrations averaged 13.3 million particles per cubic foot of air and doubtless would have been lower had not all the holes been collared dry, as conditions for maintaining low dust concentrations otherwise were excellent. Wet drilling must be supplemented by ventilation to obtain the desired control, as the water does not arrest the dust completely. If other conditions are favorable, normal ventilating currents should prove adequate but will have to be directed to the drilling operation. The most frequent objection to wet pneumatic percussion drilling is that it is disagreeable. The splashing of the water and drill cuttings and the wetness underfoot are particularly objectionable to the driller when the headroom is limited, as in many coal mines.

Various hydraulic rotary drills have been developed, and the use of water to control the dust reportedly has been applied to them successfully. The Bureau of Mines has not had opportunity to observe the results obtained.

The need for a water-distribution system or the use of inconvenient pressure tanks, the adverse effect upon some mine roof and floor, and the difficulty of using water with electric drills are other factors limiting the use of water to allay dusts from drilling. Results of tests conducted with wetting agents, foam, and various types of water sprays, all with the hope of minimizing these factors, have been unfavorable. Water sprays have proved inefficient;[14] satisfactory equipment for producing and applying foam has not been developed in the United States and thus far the performance of some wetting agents has not justified their use.[15]/[16] Further experimentation with foam and wetting agents should be conducted.

Dust Collectors

The operating principle of most dust collectors is application of exhaust ventilation near the source of the dust. Numerous dust-control systems based upon this principle have been devised for controlling dust produced by all types of pneumatic rock drills. Some of these have demonstrated that by proper application of this principal successful results could be obtained, even under difficult drilling conditions. Regardless of results, unfavorable operating features restricted their complete development. With the advent of roof drilling, the possibility that their use here might overcome the serious objections to wet drilling and the fact that they were applicable to electric rotary drilling again have stimulated their further development. To meet this need, several types of dust collectors now have been made available commercially, and others have been developed and used locally.

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[13] Williamson, W. C., and Shugert, J. L., Practical Dust Control: Min. Eng., vol. 187, 1950, pp. 86-90.

[14] Johnson, J. A., and Agnew, W. G., Dust Produced by Drilling Where Water is Sprayed on the Outside of the Drill Steel: Bureau of Mines Rept. of Investigations 3478, 1939, 6 pp.

[15] Johnson, J. A., Use of Wetting Agents in Reducing Dust Produced by Wet Drilling in Basalt: Bureau of Mines Rept. of Investigations 3678, 1943, 27 pp.

[16] Forbes, J. J , Davenport, S. J., and Morgis, G. G., Review of Literature on Dusts: Bureau of Mines Bull. 478, 1950, 333 pp.

In 1950 the Bureau of Mines inaugurated a program at the Experimental Mine, Bruceton, Pa., for testing dust-collecting devices developed commercially for application to roof drilling in coal mines. The reasons for conducting these tests were (1) to assist the designers of the equipment by evaluating the effectiveness of the devices under controlled test conditions and (2) to enable the Bureau of Mines to obtain information on dissemination of dust during roof drilling and methods of controlling it that will be beneficial to the mining industry.

Under this program, six different types of dust-collecting systems were tested for performance. Each design included a collecting head, an exhaust ventilating system, and means for removing the entrained dust load from the air passing through the system before releasing it to the mine atmosphere. The design of the hood is most important because it directly affects the dust-collecting efficiency and dictates the performance required of the other parts of the collector. Drilling in hard roof produces fine, readily transported particles, whereas drilling in soft roof, such as occurs above the Pittsburgh seam, produces large, scalelike particles that tend to plug a dust collector unless it is designed to accommodate their transport. The collectors apparently most successful have overcome this difficulty by avoiding restrictions and using the effect of gravity to full advantage in moving the drill cuttings from the hole. The provisions for a tight seal where the drill steel passes through the hood are more critical than the provision for a seal where the hood contacts the roof. Unfavorable results caused by an ineffective drill-rod seal cannot be overcome by any reasonable amount of exhaust ventilation. Either positive-pressure exhausters or air injectors can provide a sufficient rate of exhaust ventilation if the previously mentioned difficulties are avoided. Removal of the dust load from air passing through the system has been no problem, having been accomplished either by gravity separation of the large particles and mechanical filtration of the fine particles or, more simply, by mechanical filtration alone. Two collectors have been designed for removing the dust load by washing.

No attempt has been made to evaluate the features of the various collectors other than their collecting efficiencies. It is obvious that size, weight, and portability should be considered. It is noteworthy that one of the most successful dust collectors is so compact that one man can easily move it about and set it up.

The results of some performance tests have shown that it is possible to reduce roof-drilling dust concentrations to 5 million particles per cubic foot of air with dry dust collectors, and that a dust collector can perform satisfactorily with either pneumatic percussion or electric rotary drills.

The performance tests are not to be construed as approval tests, such as are conducted by the Bureau of Mines on other types of equipment under provisions of appropriate published Schedules. Such a Schedule, establishing permissibility tests, is being prepared and upon completion will allow the Bureau of Mines to grant formal approval to equipment passing the prescribed tests. One of the approval tests will require that the equipment be capable of controlling dust in accordance with the tentative Bureau of Mines recommendations previously discussed. The experience gained in testing dust collectors at the Experimental mine and in the field is being applied in the preparation of this Schedule.

Interior - Bureau of Mines, Pittsburgh, Pa.